Model Validation Using Synchrophasor Data -- A Synchrophasor Success Story

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NASPI North American SynchroPhasor Initiative

Overview

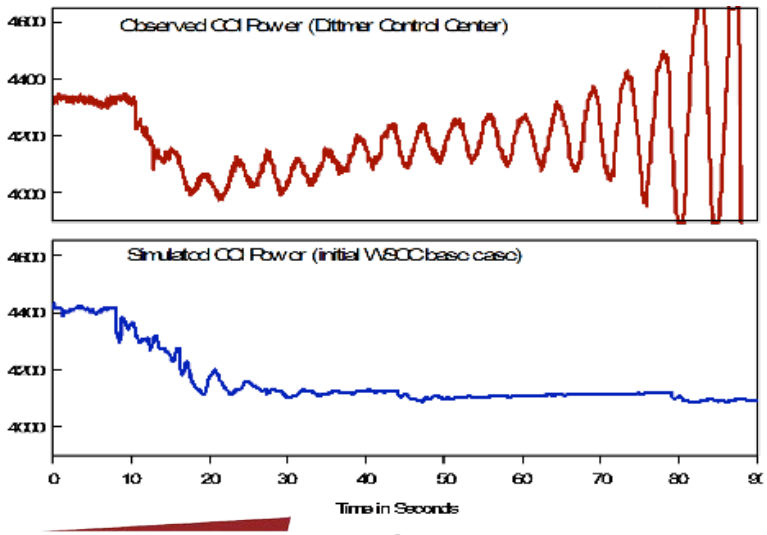
This summarizes a paper prepared for the DOE SGIG team to document the value of synchrophasor technology

- Benefits of PMU-based model validation and calibration
- How to perform model validation using synchrophasor data
- Automated model validation and calibration tools
- Examples of PMU-based model validation

WSCC August 1996 outage – real versus simulation

Real event

Dynamic simulations



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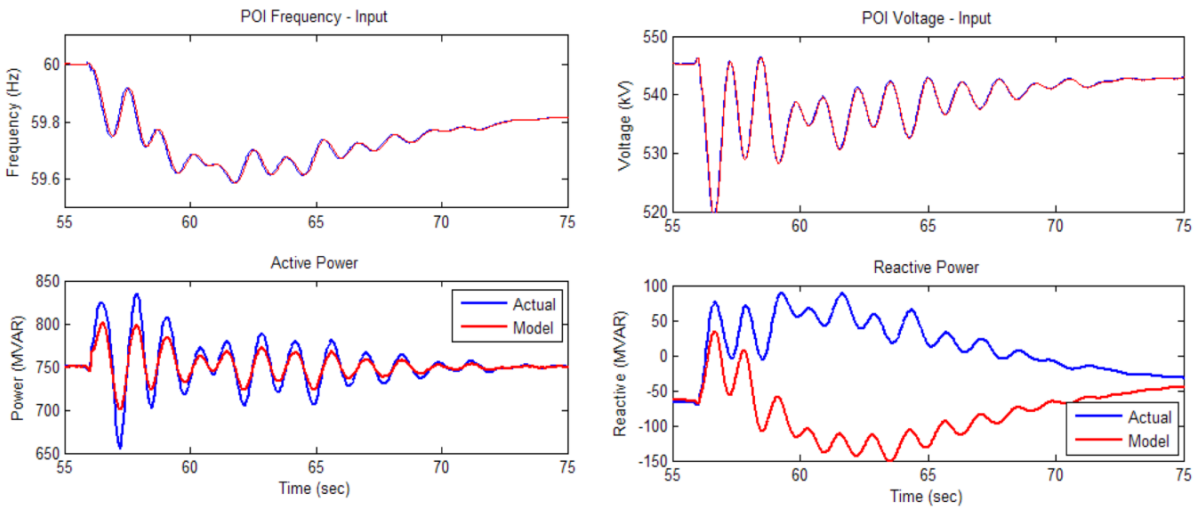
What bad models look like

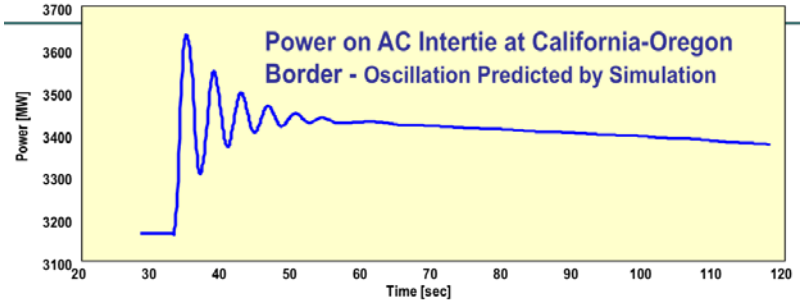
800 MW steam turbine generator (BPA)

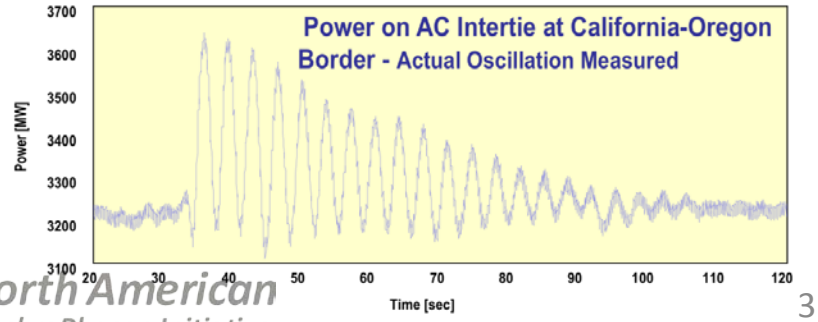
- Red = model
- Blue = actual event

AC Intertie at CA-OR border, Alberta separation from WECC, 8/4/2000 (WSCC)

- Top = simulated performance
- Bottom = actual oscillation







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Benefits of PMU data-based model validation

Since every aspect of power system planning and operation is built on mathematical models of system component operations and relationships, better models improve system operation and economics.

Synchrophasor data provide time granularity and deep visibility into the performance of individual grid components and the entire grid, capturing real performance rather than hypothesized behavior.

Specific benefits:

- Better grid operational performance from more accurate component and system models
- Better asset and system utilization and efficiency from more accurate settings and limits
- PMU-based model validation is more accurate and costs less than physical generator testing, and avoids plant shut-down and replacement power costs – savings = $50k+/plant & test
- Accepted and cost-effective way to satisfy NERC MOD-026, MOD-027, MOD-032 and MOD-033
- More accurate models let planners identify and TOs invest in correct amounts of grid and generation equipment

Relevant reliability standards

PMU-based model validation and calibration (after initial model creation) is an accepted way to meet these current and upcoming "revalidation" standards:

- MOD-026 – Verification of dynamic models and data for generator excitation/control system or plant Volt/Var control functions (2014, 2018)
- MOD-027 – Verification of models and data for turbine/governor and load control or active power/frequency control functions (2014, 2018)
- MOD-032 – data for power system modeling and analysis requirements and reporting (2015, 2016)
- MOD-033 – steady-state and dynamic system model validation – PCs to implement documented data validation process and RCs and TOs to provide actual system behavior data (2017)
- WECC Generating Unit Model Validation Policy – applies to generators down to 10 MVA/unit and 20 MVA/plant (current)

How to perform model validation using synchrophasor data

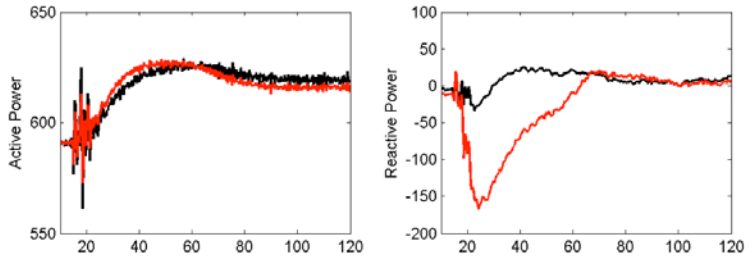
- Collect PMU data for the generator (or system) performance for one or more grid disturbance events.*
- Find the asset-specific model or a generic model for the asset
- Play the PMU data back into the model and fit simulated current and voltage to the measured values using statistical techniques. Adjust plant-specific settings (e.g., governor, exciter, stabilizer), don't just try statistical curve-fitting alone.
- If there is a close match between the simulation and the actual occurrence, then the model is validated.
- If there is a significant mismatch between model and actual, the model needs to be recalibrated (adjust model parameters further) or structurally revised.
- Repeat against multiple disturbances to produce a more robust model with better predictive capabilities.

* Useful to have requirement for PMU at generator POI

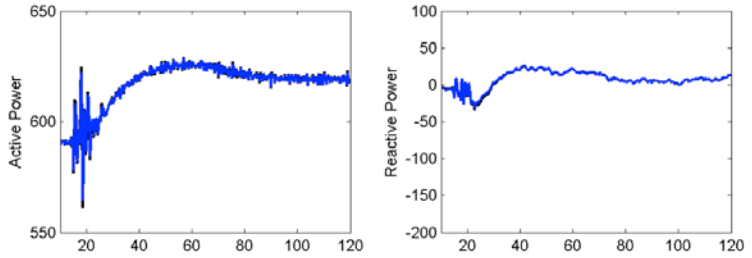
Validate or recalibrate?

Same plant, same event – black line in top graphs. Active power on left, reactive on right

- Initial model (top graphs) not a good match, needs structural revision
- Bottom graphs have structural revision and recalibration of parameters



Refute Model



Recalibrate Model

Source: B. Lesieutre, Univ. Wisconsin

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Automated model validation and calibration tools

There are several:

- EPRI Power Plant Parameter Derivation
- BPA-PNNL Power Plant Model Validation
- EPG Phasor Grid Dynamics Analyzer
- GE PSLF
- MathWorks Simulink®

Tools with phasor data play-in capability are easier to use.

Tools that automatically collect fleet data during/after events and report on matches and mis-matches between actual and predicted performance are highly valuable.

Some examples of PMU-based model validation

Synchrophasor-based model validation began in 1999 at BPA; WECC adopted Generating Unit Model Validation Policy in 2006

- Hydro generators – BPA, BuRec
- Nuclear generators – BPA, ISO-NE, Dominion
- Coal-fired generators – BPA, TransAlta
- FACTS devices – NYPA, NYISO
- Wind and solar generators – UVIG, OG&E, ERCOT
- System models – WECC
- State estimator calibration – BPA, Dominion, PJM, FPL

For more information

See extensive work by:

- WECC Joint Synchronized Information Subcommittee
- WECC Model Validation Working Group
- NASPI Model Validation Technical Workshop (10/13)
- Technical presentations and publications by:
  - Dmitry Kosterev, Steve Yang (BPA)
  - Pavel Etingov (PNNL)
  - Pouyan Pourbeik (EPRI)
  - Bernie Lesieutre (University of Wisconsin)
  - Bill Blevins (ERCOT)
  - Bob Zavadil (Enernex, for UVIG)